Biology and Distribution of *Scymnodes lividigaster* (Mulsant) and *Leptothea galbula* (Mulsant), Australian Ladybirds (Coleoptera: Coccinellidae)

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Anderson, J. M. E. Biology and distribution of *Scymnodes lividigaster* (Mulsant) and *Leptothea galbula* (Mulsant), Australian ladybirds (Coleoptera: Coccinellidae). *Proc Linn Soc. N.S.W.* 105 (1), (1980) 1981: 1-15.

Notes are presented on life stages, reproductive systems, food and feeding behaviour, longevity, parasites, predators, competitors and distribution of the aphidophagous *Scymnodes lividigaster* (Mulsant) and the mycophagous *Leptothea galbula* (Mulsant). Comments on *Amidellus ementitor* Blackburn, a ladybird superficially similar to *S. lividigaster*, are included.

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Introduction

Ladybirds have potential value in integrated pest control programmes (Hodek, 1970), yet little is known of the biology of Australian species. Hales (1979) urges investigations of ladybirds' annual cycles, prey relationships, natural enemies and physiological mechanisms related to survival, in order that their effectiveness in biological control might be assessed and exploited.

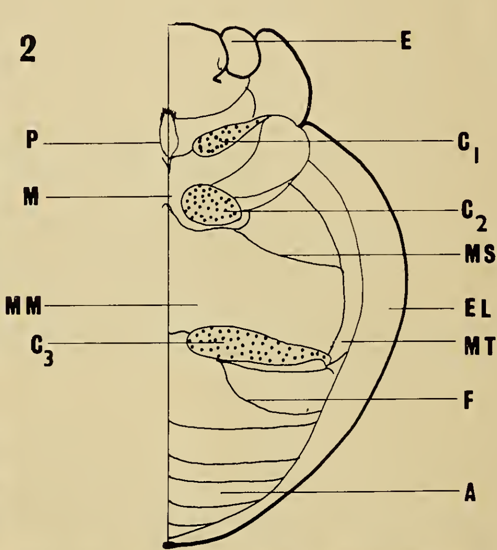
As part of a study of Australian ladybirds (Anderson, 1979; Anderson and Richards, 1977), the biology and distribution of the aphidophagous *Scymnodes lividigaster* (Mulsant) and mycophagous *Leptothea galbula* (Mulsant) are investigated and results are presented here.

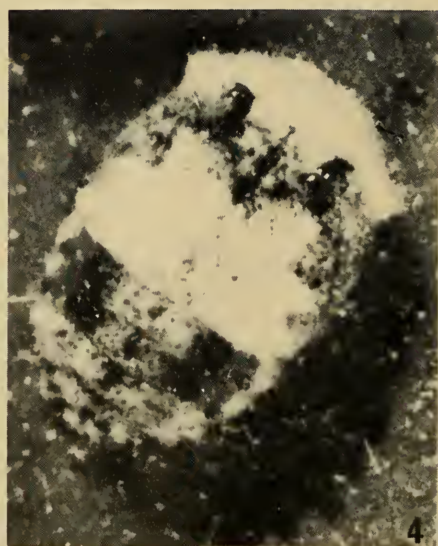
Results

Scymnodes lividigaster (Mulsant), 1853

Adult (Fig.1). Length 2-3.5 mm, width 2-2.5 mm. Body convex and pubescent; head, pronotum and elytra densely punctate. Colour black with 2 lateral lemon yellow spots on pronotum; abdomen orange-yellow; legs usually black, but yellowish in some specimens; males with yellow frons. Eyes black with small facets. Terminal segment of maxillary palp strongly securiform. Prosternum carinate, carina pointed anteriorly. Mesosternum emarginate and very slightly carinate in some specimens. Mesocoxae close together, separated by less than the width of one cavity. The femoral line ('metasternal lamella' of Blackburn (1895)) passes from posterior edge of mesosternum across metasternum to mid point of metepisternum (Fig. 2). Male genitalia (Fig. 5A) without lateral lobes (i.e. parameres); median lobe large, tubular and pointed anteriorly; sipho (Fig. 5B) slightly bent distally, flat on one side with few setae, rounded on other, with rows of tiny setae, apparently part of the internal sac, able to be ballooned out at the tip near the gonopore.

Amidellus ementitor Blackburn, 1895, closely resembles *S. lividigaster* which has led to some confusion in identification. *S. lividigaster* has been called *A. ementitor* by Hales and Carver (1976). Specimens of *S. lividigaster* from this study have been compared with the holotype of *S. lividigaster* in the British Museum (Natural History)





Scymnodes lividigaster. Fig. 1. Adult male ladybird, length 3 mm. *Fig. 2.* Ventral aspect of adult. Legs removed. (A) abdominal sternites, (C 1-3) coxal cavities, (E) eye, (EL) elytron, (F) post coxal line, (M) mesosternum, (MM) metasternum, (MS) femoral line, (MT) metepisternum, (P) prosternal carina. *Fig. 3.* Larva, 4th instar, length 6 mm. *Fig. 4.* Pupa, length 3.5 mm, attached to *Glochidion ferdinandi* leaf.

and their identity is confirmed. Two cotypes of *A. ementitor* in the South Australian Museum were examined and showed that *A. ementitor* differs from *S. lividigaster*, being smaller and slightly more pubescent and convex; femoral line meets metepisternum some distance anterior to the midpoint (cf. *S. lividigaster*, Fig. 2), male has distinct parameres (none in *S. lividigaster*, Fig. 5A), terminal segment of maxillary palp not strongly widened apically and the distance between mesocoxae greater than the width of one cavity. *S. lividigaster* is placed in the tribe Coccidulini at present, but several features including finely faceted eyes and relatively short antennae are unusual for the group (Pope, 1979). *Amidellus* is in the Scymninae, tribe Ortaliini (Sasaji, 1968). Distributions of *A. ementitor* and *S. lividigaster* overlap (Anderson, 1979), but *A. ementitor* is more common in central and northern Queensland while *S. lividigaster* is more common in coastal New South Wales and southern Queensland.

Eggs. Length 1 mm, spindle-shaped, yellow to bright orange. Laid singly in proximity of aphid colony; usually slightly on one side, in crevices, under bark, under dead and parasitized aphids or their cast skins, between plant hairs on stems and undersides of leaves, near leaf veins and inside flower buds.

Larvae (Fig. 3). Campodeiform; body elongate, tapering with armature of senti of different lengths. The armature and wax production is described by Pope (1979). First instar, length 1 mm, grey and very active, armature less pronounced than in later instars, legs long. Second instar, length 2-3 mm, grey to yellowish grey with one dark pigmented area on each thoracic notum and two darker areas on abdominal terga 2-7. Third instar, length 2.5 - 4.0 mm, colour pattern more distinctive, with orange head and pronotum and patches of white on thorax and abdomen. Fourth instar, length 3.5 - 7.0 mm, pattern similar to third instar. Larvae cease feeding some 2-3 days before pupation, attach to the substrate by the anal organ and deposit a fine heart-shaped layer of wax on the surrounding substrate. The wax is transferred from the body to the substrate with the legs.

Pupa (Fig. 4). Larval skin is shed completely and lies about the anal area. At first pupa is orange-yellow and smooth; after 1.5 h it begins to darken and white waxy secretions appear on dorsal body surface; waxy areas grow for about 36 h, particularly on head, pronotum and first three abdominal tergites, almost entirely covering pupa except for two pinkish-black shiny areas on the mesonotum devoid of wax, one similar area in the centre of metanotum, two large pink bare areas laterally on third and fourth abdominal nota and some small irregular bare areas in midline of abdominal nota posterior to the fourth.

On woody plants such as *Glochidion ferdinandi* or *Hibiscus* sp., pupae are most commonly found on bark, especially on lower sides of lateral branches, and sometimes along midribs of leaves on upper surfaces. On herbaceous plants such as *Coryza floribunda* they are found on dead and dying leaves furthest from the shoot apex. Most are found below the level of aphid infestation and observation suggests that prepupae before settling are positively geotactic. In extremely heavy infestations pupae are found on tree trunks, even in grass near trees where aphids migrate at the height of a population explosion. Pupae can erect if irritated by light or mechanical stimulation, however, they appear to be insensitive prior to emergence of the adult. Emergence is nearly always at night or early morning. Pupal skin splits dorsally in midline from head to anus and teneral adult remains on the pupal skin for up to 24 h while colouration develops and some hardening of the cuticle occurs.

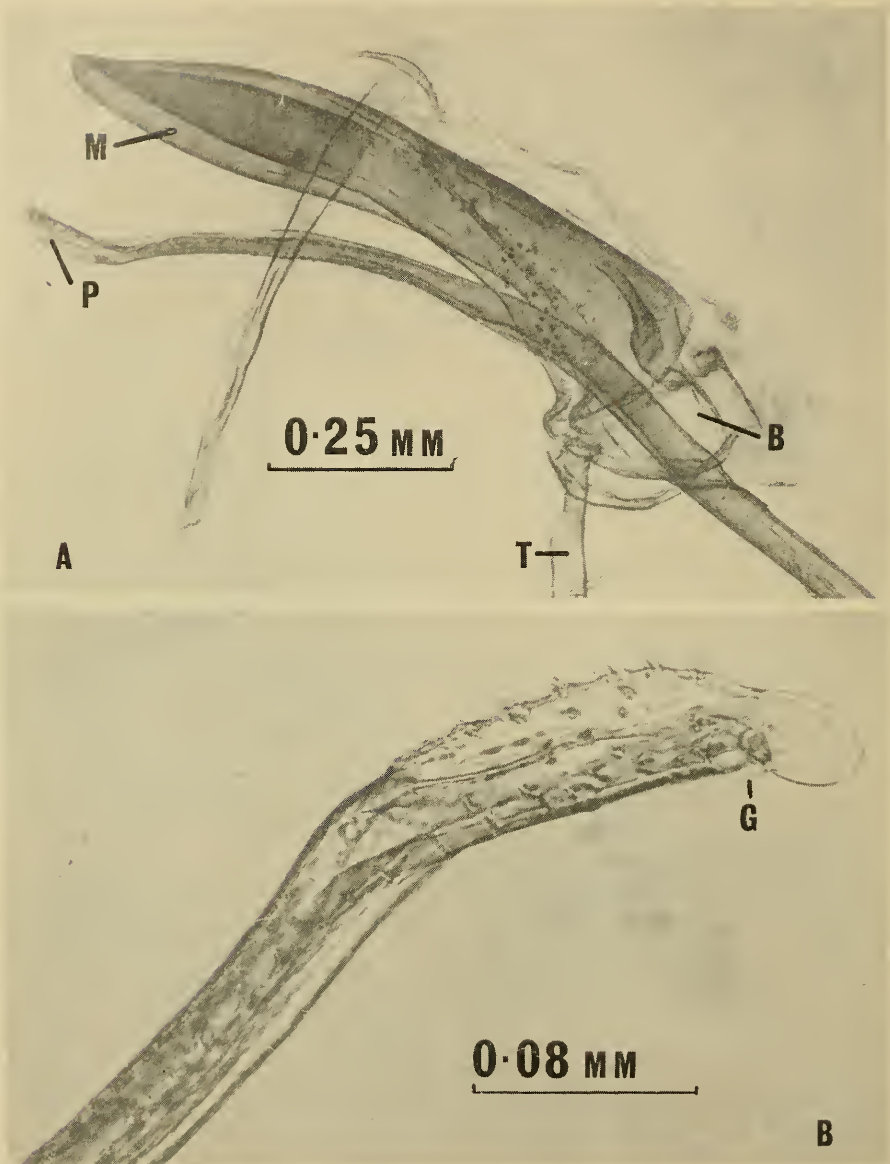


Fig. 5. Scymnodes lividigaster. **A.** Male genitalia. (M) median lobe, (B) basal piece, (T) trabes, (P) sipho. Length median lobe = 0.76 mm. **B.** Tip of sipho (P) enlarged, (G) gonopore.

Reproductive systems

Information was obtained by dissection of fresh specimens in Ringer's solution. Measurements were made with a micrometer eyepiece in a Zeiss stereoscopic microscope.

Female reproductive system is shown in Fig. 6. Ovaries paired, 7-13 ovarioles per ovary, often different numbers in each ovary of the same individual. Bursa copulatrix bright orange, beehive-shaped and ridged internally with a small funnel-shaped infundibulum anteriorly for the reception of tip of sipho. Spermatheca heavily sclerotized, hooked, attached to bursa copulatrix by a short sperm duct arising from infundibulum; spermathecal gland near infundibulum; its length half that of bursa.

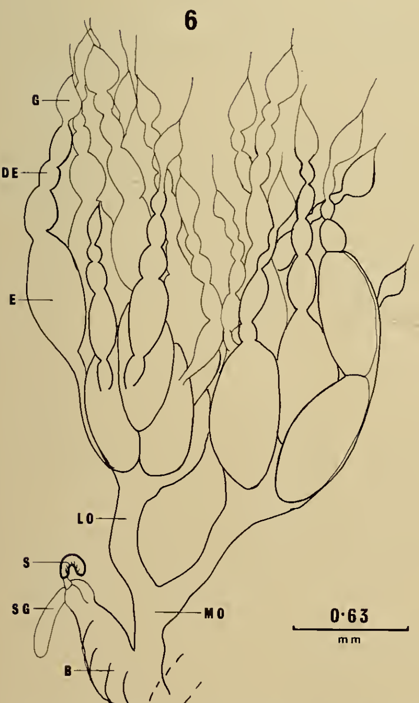
Male reproductive system shown in Fig. 7. Testes paired, 6-12 follicles in each testis, often different numbers in each testis of the same individual. Follicles joined to the vas deferens by short vas efferens; the whole appears like a bunch of small balloons. Seminal vesicle a variably sized swelling in vas, just below each testis. Two pairs of coiled accessory glands arise at junction of vasa deferentia. The united vasa deferentia, or ductus ejaculatorus join the sipho at its base.

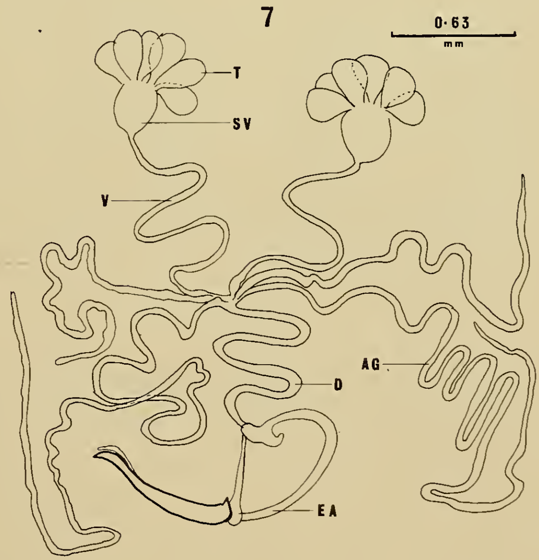
Food

S. lividigaster has been reported as aphidophagous (Schilder and Schilder, 1928; Wilson, 1960). This was tested in a series of breeding experiments, which also involved life cycle studies.

i) methods

Field-collected adult ladybirds were placed in perspex cages or gauze-covered glass specimen bottles under normal laboratory conditions, where temperature ranged from 19-27°C and fed an excess of aphid food daily. To avoid bias which might be caused by prior food consumption of parents, all adults were fed appropriate aphid species for 10 days before their eggs were used in experiments. Eggs were removed to





Scymnodes lividigaster. *Fig. 6.* Female reproductive system showing 2 ovaries consisting of ovarioles. Each ovariole has a germarium (G), a string of developing eggs (DE) and mature egg in base (E). Lateral oviducts (LO) pass to median oviduct (MO), which enters vagina as does bursa copulatory (B). Spermatheca (S) and spermathecal gland (SG) enter the distal part of the bursa copulatrix.

Fig. 7. Male reproductive system showing 2 testes consisting of a group of testicular follicles (T) which pass into seminal vesicle (SV). The vasa deferentia (V) meet and join 2 pairs of accessory glands (AG). The ejaculatory duct (D), passes to the ejaculatory apparatus (EA).

separate containers and larvae on hatching were caged individually to prevent cannabalism. Daily records of development were kept. Aphids used as food were *Toxoptera citricidus* Kirkaldy on cumquat, *Hyperomyzus lactucae* (Linnaeus) on milk thistle, *Macrosiphum rosae* (Linnaeus) on roses, *Aphis gossypii* Glover and *Rhopalosiphum padi* (Linnaeus) cultured on pumpkin and zucchini, and wheat, respectively. In life cycle experiments involving *T. citricidus* durations of early instars of some specimens were not recorded, hence a higher number of fourth instar and pupal results were obtained; with *A. gossypii*, durations of first and second instars were added together, as second instar duration was extremely short and was missed in some replicates.

Other diets were fed to field-collected adults which had been starved for 24 h, and to larvae of various instars bred in the laboratory on *A. eugeniae* or *A. gossypii*. These included an artificial diet (gelatine, vitamins, yeast, salt and 1% crushed *Aphis eugeniae* van der Goot, made into a firm jelly with hot water and thinly deposited on greaseproof paper, rolled and deep frozen until required, when it was cut into strips and hung in the cages) ; *Bombyx mori* (Linnaeus) (silkworm) eggs and larvae, *Lucilia cuprina* (Wiedemann) (Australian sheep blowfly) eggs and larvae and commercial bees pollen.

ii) results

Life cycles were completed on *T. citricidus* and on *A. gossypii* (Table 1). Mortality was high, up to 88% in experiments with *T. citricidus*. Many other life cycles were completed with *A. gossypii* on *Hibiscus* sp. and with *A. eugeniae* on *G. ferdinandi*, but these were not individually recorded. Only one life cycle from 60 attempts was completed on *M. rosae* from roses. The male adult that emerged was very small and the length of the life cycle was 38d.

No life cycles were completed with any of the other foods tested; results are presented in Table 2.

In the field adults and larvae were seen feeding on *Toxoptera ?aurantii* (Boyer de Fonscolombe) on *Cassia* sp., *Brachycaudus helichrysi* (Kaltenbach) on sunflower, *Aphis nerii* (Boyer de Fonscolmbe) on *Araujia hortorum*, *Aphis gossypii* Glover on *Bidens pilosa* and *Ablutilon indicum*, and *Aphis citricola* (van der Goot) on *Coryza floribunda*. Healthy adults emerged from pupae collected on these hosts.

TABLE 1

Duration of the life cycle of *Scymnodes lividigaster* fed two different aphid foods, *Toxoptera citricidus* on cumquat and *Aphis gossypii* on cucurbits. n = number of ladybirds. d = mean number of days (± 2 standard errors). Life cycle is from egg to adult.

Aphid Food		Duration of Instars (in days) Egg	1	2	3	4	pupa	Total adults	Range (days)
T. citricidus	n	20	11	10	10	13	18	8	
	d	4.6 (0.55)	2.4 (0.40)	3.1 (1.59)	1.5 (0.33)	4.5 (1.51)	7.3 (0.96)	26 (7.64)	13-36
A. gossypii	n	26	26		24	22	11	11	
	d	4.4 (0.47)	4.2 (0.57)		2.0 (0.42)	4.4 (0.80)	6.5 (1.77)	22 (1.73)	19-29

Feeding behaviour

Adults observed in the field had speedy and vicious eating habits, snatching aphids from behind and moving quickly to a clear zone, where aphid, appendages and all, was dispatched in 3-5 min. Well-fed adults and larvae in culture were lackadaisical and tended to eat only soft parts of the aphid, rejecting thorax and appendages. Larvae in field and laboratory attack and consume aphids many times their own size. They hover near an aphid, waving their forelegs rhythmically, then move their head up and down the aphid's back for about 2 minutes, finally lunging mandibles into the aphid body in 6-7 distinct movements while still waving their legs. They then begin to suck out body contents and lift aphid from the substrate, thereby removing rostrum from leaf tissue. Aphid body contents are withdrawn and replaced up to 35 times, the process taking a maximum of 18 minutes to complete and indicating extra intestinal digestion. The final 'blow-up' bloats the aphid enormously and after deflating, the larva either shakes the shrivelled aphid exoskeleton free, wipes it off on a nearby plant or scrapes it off between its forelegs. One larva was observed to suck at a parasitized aphid 'mummy', but in this instance, parasitism was high and unaffected prey in short supply.

A. gossypii is nearly always attacked by larval ladybirds from behind. When attacked, aphids raise their abdomen and a drop of liquid appears on the end of each cornicle; sometimes they kick at the ladybird with their long hind legs and a huge drop of liquid is extruded from the aphid anus. These latter measures did not deter larger larvae, but may have been effective in allowing aphids to escape from small larvae. No escapes by dropping from plants were observed.

Longevity

A culture of *S. lividigaster* (n = 8) was kept alive for 5 months in the laboratory between March and August, 1976, when temperature varied between 15-24°C. This is a short time compared with other ladybirds kept under the same conditions during

TABLE 2

Diets fed to *Scymnodes lividigaster* which did not complete the life cycle. Number tested with each diet = 20.

Type of Diet	Result
Artificial diet	Accepted readily by adults and larvae but no development of larvae, death. After 6 weeks adults showed 70% mortality, produced no eggs and no fat body was laid down. Mating not observed, but all individuals were seen to consume the diet
Bombyx mori eggs and larvae (2-3 mm)	Not accepted by adults or larvae
Lucilia cuprina eggs and larvae (>2.5 mm)	Not accepted by adults or larvae, though one adult was seen scraping at a squashed fly larva
Hyperomyzus lactucae	Accepted, but no eggs laid. Adults died within a week. Possibly toxic. Larvae not tested
Rhopalosiphum padi	Accepted, but no eggs laid. Adults released after 3 weeks — not toxic. Larvae not tested
Commercial bees pollen	Accepted readily by adults, no long term experiment carried out. Larvae not tested

1976-1977. *Coccinella repanda* Thunberg*, *Micraspis frenata* Erichson*, *L. galbula**, *Archaioneda princeps* Mulsant and *Parapriasus* sp. were kept alive for 14 months and *Coelophora inaequalis* (Fabricius) for 12 months (unpublished data). The *S. lividigaster* result probably reflects poor nutrition rather than life span. Great difficulty was experienced in supplying suitable live aphids continuously; stocks of frozen aphids ran out in mid winter 1976, when life cycle work was in progress and no suitable long term alternative food was found. Field monitoring indicated that *S. lividigaster* females certainly overwintered, having laid eggs in the previous autumn (March, April) and presumably would lay again in spring (October). This encompasses a life span of at least 8 months.

Parasites, predators and competitors

Published records of parasitism of coccinellids in Australia (Timberlake, 1920; Hales and Carver, 1976) contain no records for *S. lividigaster* and no parasites were discovered in the course of the present study. The major predator and competitor of *S. lividigaster* was found to be the ladybird *C. inaequalis*. Adult *C. inaequalis* were observed to eat larvae, pupae and teneral adults of *S. lividigaster,* and *C. inaequalis* larvae ate *S. lividigaster* larvae as abundance of aphids decreased on host plants. Some protection from predation by *C. inaequalis* was no doubt afforded to *S. lividigaster* larvae by their armature of senti. More importantly, normal behaviour of *S. lividigaster* larvae and prepupae protected them in space from predation by *C. inaequalis*. Larger larvae of *C. inaequalis* were most commonly found at leaf tips, less often beneath leaves, where smaller *S. lividigaster* larvae congregated. *S. lividigaster* prepupae moved downwards away from the aphid infestation to pupate, while those of *C. inaequalis* pupated close to aphid colonies, seldom on bark, so that on emergence, these teneral adults were separated. Evidence suggests that prepupae of each species have different geotactic and possibly phototactic responses. Another important factor in separating these potential ladybird competitors was timing of their life cycles, which were separated by approx. 10 d. *S. lividigaster* was always first to reproduce and its pupae were those first recorded in the field. Predominance of *C. inaequalis* pupae normally signalled the end of aphid infestation in any one area. This timing difference, behavioral spacing of larvae and pupae, together with greater armature of *S. lividigaster* larvae, reduced competition between ladybird species and predation was observed only when aphid populations were declining.

Distribution

Locality data of *S. lividigaster* were obtained from specimens in The Australian Museum, Sydney; The Australian National Insect Collection, Canberra; New South Wales Department of Agriculture, Sydney; Department of Primary Industries, Brisbane; The University of Queensland, Entomology Department, Indooroopilly; The Queensland Museum, Brisbane; The South Australian Museum, Adelaide; The National Museum of Victoria, Melbourne; Bernice P. Bishop Museum, Honolulu, Hawaii; Department of Scientific and Industrial Research, New Zealand; British Museum (Natural History), London; and author's collection, detailed in Anderson (1979). Identifications were based on male genitalia and examination of thoracic sterna. In Australia, the range of *S. lividigaster* extends from Nowra in southern New South Wales to Thursday Island in North Queensland, but appears to be restricted to the coastal fringe. It is apparently common in the Brisbane area (K. J. Houston, pers. comm.) and in the Sydney region.

S. lividigaster was introduced into West Australia in 1902, but it apparently

* released after 14 months in culture.

failed to establish (Jenkins, 1946). A collecting trip in 1980 to Western Australia yielded no specimens. It is common in the Cook Islands on Rarotonga, Aitutaki and Atiu, where it was possibly introduced for biological control purposes. The earliest record of its presence in the Cook Islands is 1911 (New South Wales Dept. Agric.). Locality records show it recorded in New Zealand in 1961 (D.S.I.R.) and it appeared in Auckland late in 1976 (J. C. Watt, pers. comm.). It was introduced to Hawaii in 1894 (Swezey 1915, 1923) and is now well-established there (G. A. Samuelson, pers. comm.). It has been collected in the Austral, Society, and Gilbert Islands between 1969-1977 (Brit. Mus. (Nat. Hist.)).

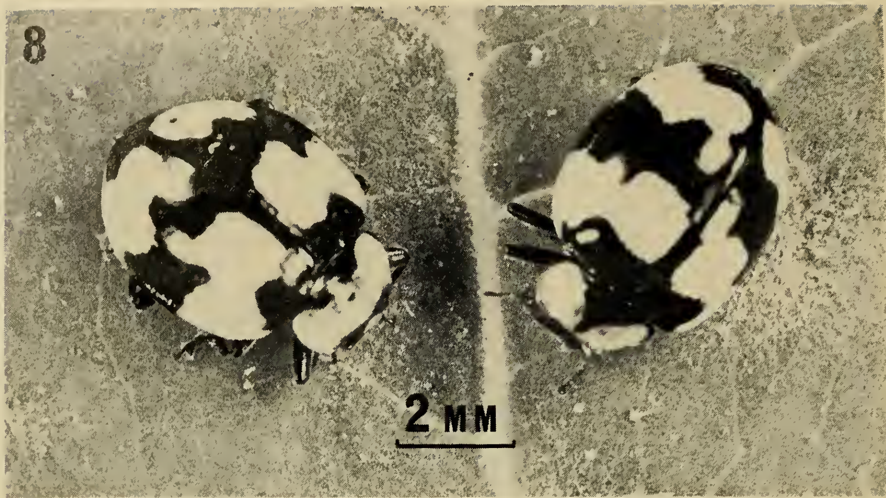
Leptothea galbula (Mulsant), 1850

Adult (Fig. 8). Length 3-5.0 mm, width 2.0 mm, oval and glabrous, with characteristic lemon yellow and black patterning on head, prothorax and elytra, totally black ventrally. Pronotum much narrower than elytra, only barely emarginate anteriorly with broadly rounded anterior angles. The sexes cannot be reliably differentiated externally as is often the case in the family Coccinellidae (Hodek, 1973; Blackman, 1974) and dissection was found to be essential for accurate sexing. *Leptothea* is in the tribe Psylloborini of the Coccinellinae (Sasaji, 1968).

Eggs. Length 2 mm, spindle shaped, white, laid in clusters of 2-28, most commonly 7-8. Eggs laid on their ends, particularly on white patches of the fungus *Oidium* sp., on undersides of leaves, sometimes on stems, rarely on upper leaves. Eggs seldom laid on smooth cotyledons of cucurbits, nearly always on rough veined or hairy parts, possibly indicating a thigmotactic influence. In culture, females laid readily on white cotton wool and under white filter paper. Young females tended to lay preferentially on cotton wool, while females older than 2 weeks, showed preference for cucurbit leaves.

Larvae (Fig. 9). Campodeiform, with elongate, tapered body; armature reduced to stumpy senti. 1st instar, length just exceeding 1 mm, white on emergence, but larvae remain on egg capsule for up to 18 h after hatching, during which time they become light grey with some darker markings. 2nd to 4th instar larvae very characteristically patterned; head and prothorax yellow, rest of body white with 6 large black spots on prothorax and abdominal segments 1-8; and 8 spots on meso— and metathorax. Length of 2nd instar = 6 mm, 3rd instar = 7 mm, 4th instar = 10 mm. Prepupae cease feeding and attach to substrate with anal adhesive organ, after which some contraction of body occurs prior to pupation.

Pupa. The larval skin is shed completely and lies about anal organ. Pupa initially white and smooth, but melanic patterning quickly appears on thorax and abdomen, followed by yellow colouration of prothoracic and anterior abdominal regions. Patterning in black consists of stripes; 1 on lower edge of pronotum and one lengthwise in mid elytron; of dots; 2 on meso-metathorax and abdominal segment 6, 4 on abdominal segments 2 and 4; of black tipped protruding flanges; at tibia-femur elbow of each leg and laterally on abdominal segment 3. There are smaller unpigmented flanges on abdominal segments 4 and 5. Pupae erect in a similar manner to *S. lividigaster* when stimulated by heat, light or touch. Pupae are found under the older leaves and often cluster together in groups of up to 30. Certain pupae seem very attractive to male adults which may sit on a pupa for up to 5 d until eclosion. The male steps from pupal skin onto teneral's back on emergence and continues to cling there until wings are expanded, dried and withdrawn. Mating may then occur, before hardening is completed. Male aggression is associated with this behaviour (Richards, 1980)

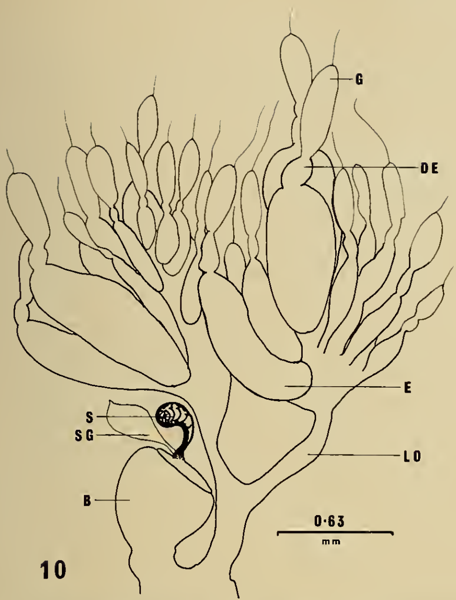


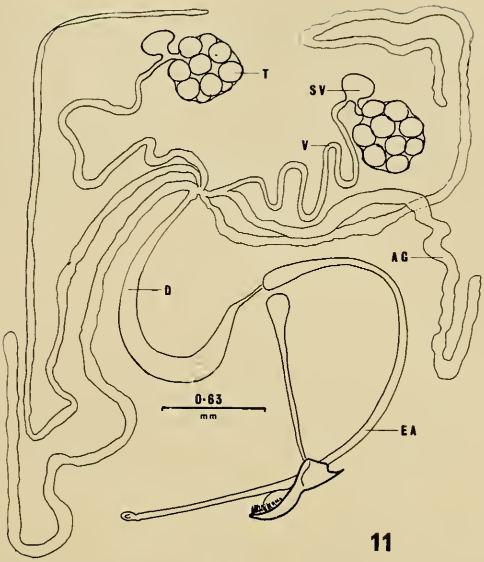
Leptothea galbula. Fig. 8. Adults. Length = 5 mm. *Fig. 9.* Second instar larvae. Length = 2.0 mm.

Reproductive systems

Method of examination similar to that used for *S. lividigaster*. Female reproductive system (Fig. 10) with same components as *S. lividigaster*, but differing in overall size and shape. Ovaries white, ovarioles vary from 9-12. Bursa copulatrix acorn-shaped, lightly sclerotized except for soft upper surface. Spermatheca black, heavily sclerotized, rounded anteriorly and hooked, passing into centre of upper surface of bursa; at junction of the two, a flattened, leaf-shaped spermathecal gland is attached.

Male reproductive anatomy (Fig. 11), basically similar to *S. lividigaster*, except





Leptothea galbula. Fig. 10. Female reproductive system. Labelling as in Fig. 6.
Fig. 11. Male reproductive system. Labelling as in Fig. 7.

for presence of 2 well-developed parameres. Each testis with 6-10 follicles. Testes smaller in diameter than *S. lividigaster*, despite the larger size of *L. galbula*. Seminal vesicle kidney-shaped and appears to be an offshoot of vas deferens, rather than a swelling of the vas.

Food

L. galbula has been described in association with aphids and scales (Froggatt, 1902). However, Koebele observed adults in association with powdery mildew (*in* Timberlake, 1943) and Schilder and Schilder (1928) similarly reported the ladybird's association with this fungus.

i) methods

Experiments were set up to determine whether powdery mildew *Oidium* sp. on cucurbits is an essential food of *L. galbula*; (a) where ladybirds were reared together in large numbers in constant temperature of 22 ± 2°C and constant light (LL), (b) where ladybirds were reared one per leaf in normal daylengths of approx. 13 h and temperature 20-25°C. Large perspex cages were used for experiments and ample fungal food supplied, plus sugar and water. In another experiment, *L. galbula* was fed a series of foods; the artificial diet previously described; *B. mori* larvae and eggs; *L. cuprina* larvae and eggs; aphids *T. citricidus, A. gossypii, H. lactucae, R. padi* and *M. rosae*, and commercial bees pollen. These foods were placed in Petri dishes with individual ladybirds.

ii) results

In both experiments involving powdery mildew, life cycles were completed (Table 3). Mortality was extremely low in the first experiment and zero in the individually monitored second experiment. Beetles offered any of the other foods did not complete their life cycle; the results are in Table 4.

TABLE 3

Duration of the life cycle of *Leptothea galbula* fed *Oidium* sp. (powdery mildew) on cucurbits. (a) larvae reared in groups in LL at 22 ± 2°C and (b) larvae reared individually in LD 13:11 at 20-26°C. n = number of ladybirds. d = mean number of days (± 2 standard errors).

(a)

Food	n	Mean duration of life cycle (d)	Range (days)
Oidium sp.	184	20.96 ± (0.45)	16-26

(b)

Food	Duration of Instars (d)									
	n	Egg	1	2	3	4	pre pupa	(4 + prepupa)	pupa	Total mean	Range (days)
Oidium sp.	17	3.0 (0.00)	3.7 (0.23)	2.3 (0.29)	2.2 (0.40)	3.8 (0.54)	2.5 (0.31)	6.3 (0.53)	5.2 (0.20)	22.6 (0.83)	20-26

In the field *L. galbula* was observed breeding regularly on *Oidium* sp., on *Lonicera fragrantissima* and cucurbits, and spasmodically on chrysanthemums.

Feeding behaviour

Feeding behaviour is remarkably uniform, both larvae and adults graze fungal spores and hyphae from surfaces of leaves. When *Oidium* sp. is dense, they feed on a front and visibly clear large areas of the leaf's white fungal covering; if infestation is light, both larvae and adults search leaf surfaces at random and if nothing is found, adults fly off. Adults and larvae are cannibalistic, eating their own eggs, but not larvae. Thus they can be reared in batches; in the field, high populations may build up in small areas.

Longevity

A culture of *L. galbula* (n = 5) was kept in the laboratory in similar conditions to that of *S. lividigaster* for just over 14 months when ladybirds were released. Mortality was minimal and reproduction almost continuous.

Parasites and competitors

The only possible parasite of *L. galbula* noted was a mite found attached to the body of adults. It was observed only after wet periods when habitats were overwatered, so its impact was apparently unimportant. No predators were observed at any stage. The only competitor, is the leaf-eating ladybird *Henosepilachna vigintioctopunctata* (Fabricius), which feeds on cucurbits and will eat leaves infected with powdery mildew. However, it poses no real threat.

Distribution

Locality data were obtained from institutions previously mentioned in the distribution of *S. lividigaster* and detailed in Anderson (1979). *L. galbula* is recorded along the east coast of Australia from Ferntree Gully in Victoria to Mossman in North Queensland and as far west as Warrumbungle National Park in New South Wales. It is abundant in the Sydney area and is common in Brisbane gardens, especially when crepe myrtle *Lagerstroemia* sp. becomes infested with powdery mildew (E. C. Dalms, pers. comm.).

TABLE 4

Diets fed to *Leptothea galbula* which did not complete the life cycle. Number tested with each diet = 20.

Type of Diet	Result
Artificial diet	Accepted very readily by adults and larvae, but no development of larvae, death. Adults showed a 90% mortality, after 6 weeks. Survivors dissected were in diapause with large fat body and gonotrophic regression. No eggs were laid and no mating was observed despite continual feeding
Bombyx mori eggs and larvae (2-3 mm)	Untouched by adults and larvae
Lucilia cuprina eggs and larvae (>2.5 mm)	Untouched by adults or larvae. Active avoidance if approached by a blowfly larva
Aphids	Untouched by adults or larvae. Active avoidance if approached
Commercial bees pollen	Accepted readily by adults, no long term experiment carried out. Larvae not tested

Discussion

Life stages and reproductive anatomy of *S. lividigaster* and *L. galbula* conform to the basic coccinellid type (Hodek, 1973) and variation in number of testicular follicles and ovarioles of certain individuals and between individual ladybirds is not unusual (Robertson, 1961; El Harari, 1966). However, of particular interest is the male genitalia of *S. lividigaster* which lack parameres. The primitive coccinellids of the tribe Serangiini have very small or vestigial parameres (Sasaji, 1968), whereas most other ladybirds have parameres (Ehara, 1952; Smirnoff, 1957; Sasaji, 1968).

The waxy 'heart' which surrounds the prepupa and pupa of *S. lividigaster* may be protective in function, as small wasps and ants were observed to skirt round the rim of the wax. There is no record of any such secretion in any other ladybird.

The ladybirds exhibit a high degree of food specificity; *S. lividigaster* is aphidophagous and *L. galbula* is mycophagous. Other foods offered did not allow completion of the life cycle. Not all aphid species promoted reproduction in *S. lividigaster*. *T. citricidus, A. gossypii* and *A. eugeniae* are suitable essential foods that allow completion of the life cycle normally; whereas *M. rosae* is a very poor essential food. The aphid *R. padi* was found to be a non-toxic alternative food, whilst *H. lactucae* was accepted, but was probably toxic. *H. lactucae* was toxic to *C. inaequalis* (Hales, 1976), but Houston (1979) reared this ladybird for several generations on that aphid. K. J. Houston (pers. comm.) suggests a sudden change in diet can be detrimental to ladybirds, especially larvae. Field observations indicate a number of other aphid species may act as essential food for *S. lividigaster*.

For *L. galbula, Oidium* sp., the imperfect form of the pathogenic fungus, powdery mildew, was the only essential food discovered, though other foods were accepted and a few adults laid down fat on the artificial diet. In other experiments with ladybirds *Micraspis frenata* Erichson and *C. inaequalis*, it was found that the artificial diet and *Tribolium confusum* Jacquelin du Val (flour beetle) larvae and pupae acted as alternative food and mortality was negligible. Infertile eggs were laid by *M. frenata* (unpublished data). This indicates the narrow food specificity of *S. lividigaster* and *L. galbula* compared with more polyphagous species which live side by side with them in the study area. Even less specificity is reported in some overseas polyphagous ladybirds such as *Coleomegilla maculata* (De Geer) (Attalah and Newsom, 1966) and *Harmonia axyridis* Pallas (Matsuka and Okada, 1975). Meridic artificial diets have been concocted for them. To date, despite the food preferences of *S. lividigaster* and *L. galbula* there is no useful information on the economic impact of either species.

Mean duration of the life cycle of *S. lividigaster* is very similar to that of other aphidophagous species from temperate regions (Davidson, 1923; Thompson, 1926; Bagal and Trehan, 1948; Hales, 1976), but is shorter than that recorded from cool temperate regions (Hawkes, 1920), while that of *L. galbula* compares favourably with other mycophagous ladybirds (Kapur, 1943; Bagal and Trehan, 1948).

Very high mortality experienced in breeding experiments with *S. lividigaster* may have been due to size of aphids supplied. Newly hatched ladybird larvae have difficulty in capturing their first aphid (Dixon, 1959) and cannot manage large ones (Dixon, 1959; Gurney and Hussey, 1970). No size-selection of aphids was made during experiments and this may have prejudiced survival of smaller larvae, especially in experiments with large *T. citricidus* aphids.

Coccinellids are known to be long lived insects and it would not surprise to find that *S. lividigaster* and *L. galbula* lived for periods of over a year in the field. Hodek (1973) reports coccinellid field life spans of two or three years and Smith (1965) kept *Anatis mali* (Say.) alive in culture for over 1000 d and *C. maculata* for over 400 d fed on various synthetic foods. It appears that alternative foods enhance longevity, whereas essential foods allow reproduction but life span is reduced (Smith, 1965).

Acknowledgements

Most of the work in this paper was carried out at the University of New South Wales during tenure of a Linnean Macleay Fellowship awarded by the Linnean Society of New South Wales; other investigations were made possible by an Australian Museum Postgraduate Award in 1977. I thank Mr Ken J. Houston and Mr Bryan Cantrell of the Dept of Primary Industries, Entomology Branch, Indooroopilly, Queensland and Associate Professor Erik Shipp, School of Zoology, University of New South Wales, who read the original manuscript and made many helpful suggestions.

Dr V. F. Eastop, British Museum (Natural History), was kind enough to identify for me the aphids associated with this study. Dr Aola M. Richards, University of New South Wales, and Mr R. D. Pope, British Museum (Natural History), assisted me with the naming of the ladybirds.

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